CYCLOTRON ACCELERATION OF HEAVY IONS AND THEIR USE IN SOME NUCLEAR INVESTIGATIONS

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UPPSALA 1959

Almqvist & Wiksells Boktryckeri AB

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INAUGURAL DISSERTATION

By

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BY DUE PERMISSION OF THE FACULTY
OF SCIENCE OF THE UNIVERSITY OF UPPSALA
TO BE PUBLICLY DISCUSSED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN THE LECTURE HALL OF
THE INSTITUTE OF PHYSICS ON MAY 25, 1959,
AT 10 A.M.

UPPSALA 1959

Almqvist & Wiksells Boktryckeri AB

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BIBLIOTHEEK
LEIDEN

Cyclotron acceleration of heavy ions and their use in some nuclear investigations

Since 1953 the fixed-frequency 225-cm cyclotron at the Nobel Institute of Physics, Stockholm, has been used extensively for acceleration of heavy ions (i.e., ions of atomic number greater than 2). The present dissertation deals with the 225-cm cyclotron and its use for heavy-ion acceleration, as well as with some investigations performed by means of carbon, oxygen and neon ions accelerated in this machine.

A summary is given below of the following papers:

I. H. Atterling and G. Lindström: The 225-cm cyclotron at the Nobel Institute of Physics, Stockholm. *Arkiv för Fysik 15*, 483 (1959).

II. H. Atterling: The acceleration of heavy ions in the Stockholm 225-cm cyclotron. *Arkiv för Fysik 15*, 531 (1959).

III. H. Atterling, W. Forsling, L. W. Holm, L. Melander, and B. Åström: Element 100 produced by means of cyclotron-accelerated oxygen ions. *The Physical Review 95*, 585 (1954).

IV. H. Atterling and W. Forsling: Light polonium isotopes from carbon ion bombardments of platinum. *Arkiv för Fysik 15*, 81 (1959).

V. H. Atterling, W. Forsling, and B. Åström: Neutron-deficient polonium isotopes from neon ion bombardments of wolfram. *Arkiv för Fysik 15*, 279 (1959).

VI. R. B. Leachman and H. Atterling: Nuclear collision stopping of astatine atoms. *Arkiv för Fysik 13*, 101 (1957).

VII. H. Atterling. J. Beydon, M. Crut et J. Olkowsky: Transmutation du cuivre par le carbone, l'oxygène et le néon. *Nuclear Physics 2*, 619 (1956/57).

VIII. M. Crut, H. Faraggi, J. Olkowsky et H. Atterling: Comparaison des réactions $^{59}Co + {}^{20}Ne$ et $^{63}Cu + {}^{16}O$. *Nuclear Physics 2*, 624 (1956/57).

SUMMARY

In paper I a description is given of the Stockholm 225-cm cyclotron. An unusual feature of this machine is the dee biasing system based on the use of condensers as electrical terminations of the dee stems. The cyclotron has been operating for several years producing internal beams of protons, deuterons, alpha particles and heavy ions. With the present oscillator frequency a nominal energy of about 11 MeV/nucleon is attained at a radius of 90 cm.

The work on acceleration of heavy ions in the 225-cm cyclotron is the subject of paper II. With the oscillator frequency used since April 1955, this cyclotron can accelerate ions with mass-to-charge ratios up to about 3.7. So far the following ions have been accelerated: $^{12}C^{6+}$, $^{12}C^{4+}$, $^{13}C^{4+}$, $^{14}N^{6+}$, $^{16}O^{6+}$, $^{20}Ne^{6+}$ and $^{22}Ne^{6+}$. A description is given of the acceleration and bombarding techniques used in this work. Some results of an investigation of the energy distribution of $^{12}C^{4+}$ beams are reported. It is shown that this distribution contains, in addition to the high-energy peak of $^{12}C^{4+}$ ions, also a low-energy component.

In 1954 a series of experiments using the oxygen beam in the 225-cm cyclotron, led to the first production by means of heavy ions of an isotope of element 100 (^{250}Fm). This work is reported in paper III. At the time when these experiments were made, the only instrument available for the determination of alpha energies was a 16-channel pulse-height analyzer and an ionization chamber without a grid. The mass assignment was later confirmed by experiments at the University of California Radiation Laboratory, Berkeley, whereas the energy value turned out to be somewhat too high.[1]

Paper IV reports an investigation of neutron-deficient polonium isotopes produced by bombarding platinum with ^{12}C and ^{13}C ions. One of the alpha activities found was assigned to ^{203}Po. For ^{202}Po a half-life considerably shorter than that reported by other investigators has been obtained.

Paper V concerns a study of alpha-decay properties of neutron-deficient polonium isotopes produced by bombardments of wolfram targets with ^{20}Ne and ^{22}Ne ions. One of the isotopes produced was assigned to ^{196}Po. In two experiments an alpha activity with a half-life of about 0.5 minutes and with an alpha-particle energy of approximately 6.23 MeV was observed. This activity is probably identical with one reported by Tove[2] and assigned to ^{195}Po.

Using ^{12}C ions, an investigation of nuclear collision stopping of astatine atoms has been made. In this study, which is reported in paper VI, the ranges

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[1] S. Amiel, A. Chetham Strode, Jr., G. R. Choppin, A. Ghiorso, B. G. Harvey, L. W. Holm, and S. G. Thompson, Phys. Rev. *106*, 553 (1957). In this paper the alpha-particle energy of ^{250}Fm is given as 7.43 MeV.

[2] P. A. Tove, Arkiv för Fysik *13*, 549 (1958).

and range stragglings of astatine atoms in aluminium and silver have been measured. The reactions ^{197}Au (^{12}C, xn)At have been used to provide astatine atoms with velocities near the Bohr velocity v_0, for which stopping occurs principally by nuclear collisions. The experimental range stragglings are in satisfactory agreement with straggling values obtained theoretically.

The work reported in paper VII is a study of radioactive products obtained by bombarding copper with ^{12}C, ^{16}O and ^{20}Ne ions in the 225-cm cyclotron. The relative yields for various nuclides produced in this way are given.

Paper VIII reports an investigation, part of which has been made with heavy ions in the cyclotron at Centre d'Études Nucléaires de Saclay, and part with heavy ions in the Stockholm cyclotron. A study of the reactions ^{59}Co + ^{20}Ne and ^{63}Cu + ^{16}O has been made on the basis of a comparison of the relative yields of the reaction products obtained in the two cases.

ACKNOWLEDGEMENTS

I should like to express my gratitude to the Director of the Nobel Institute of Physics, Professor Manne Siegbahn, for his continued interest and generous support in this work.

I should also like to thank Professor Kai Siegbahn for his constant encouragement.

Finally, I am very much indebted to all my collaborators and to all members of the Institute who have contributed, in various ways, to the present work.

Stockholm, April 1959. *Hugo Atterling*